A History of Military Mapping Camera Development

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I. Introduction

For many years the Army's Corps of Engineers has held the prime responsibility for the military development of map plotting equipment and for topographic mapping techniques in general. With the advent of the airplane, responsibility for the development of mapping cameras and other airborne mapping and surveying equipment was placed with the Army Air Corps. As a result, in 1920, the Army organized, at what is now Wright-Patterson Air Force Base, the Wright Field Military Detachment. This group was assigned as a branch of the Engineer Board at Fort Belvoir, Virginia, in the early part of World War II. The Engineer Board was reorganized several years later to form the U. S. Army Engineer Research and Development Laboratories. The present aerial mapping liaison group at Wright-Patterson Air Force Base is now a part of the U. S. Army Engineer Geodesy, Intelligence and Mapping Research and Development Agency, Fort Belvoir, Virginia, which operates directly under the Chief of Engineers.

In the Air Force, the development of aerial mapping cameras and accessory equipment was handled originally by the former Engineering Division of Air Materiel Command and its predecessors. Since then, these developments have been conducted by the Photographic Laboratory, by the Aerial Reconnaissance Laboratory, and now by Reconnaissance Systems Division of the Deputy Commander/Engineering, Aeronautical Systems Division, Wright-Patterson Air Force Base. During the period 1948–1960, Mr. Leonard W. Crouch, now of Reconnaissance Laboratory, DC/T, ASD, was the Air Force Project engineer on aerial mapping camera development. Largely through his efforts in this period the military mapping camera became the highly precise, extremely reliable instrument that it is today.

The past forty years has seen the development in the Air Force of two lines of aerial cameras—the reconnaissance series and the mapping series. This division in development was influenced by the differing needs of the Army and the Air Force. In its prime responsibility for targeting, charting and reconnaissance interpretation, the Air Force has insisted that the major consideration in the development of reconnaissance cameras be the enhancement of photographic resolution. Hence, work in this area has included the development of lenses with high resolving power, films capable of producing high resolution, film magazines with image-motion compensation capabilities, and gyroscopically stabilized aerial camera mounts which reduce vehicle vibrations and acceleration effects.

The prime requisite of the Corps of Engineers for a mapping camera is a high degree of dimensional stability in the camera-lens-film combination to produce photography capable of direct application to map compilation. Therefore, mapping camera development has been characterized by the production of frame-type cameras having low-distortion lenses, lens cones fabricated from alloys providing high structural stability and with fiducial markers placed on the lens cone rather than on the magazine, also between-the-lens shutters, and appropriate data recordings which appear on the film negative between frames. The cameras are stocked with low differential distortion, topographic base films, and are installed in stabilized aerial camera mounts. Development of mapping cameras is accomplished by the Air Force upon imposition of Corps of Engineers requirements. This work has been supported actively through the years by the previously mentioned Corps of Engineers personnel who have been assigned to duty at Wright-Patterson Air Force Base.

II. Older Cameras (1920–1939)

The first camera of the mapping series was the *Type T-1*, which was developed in the

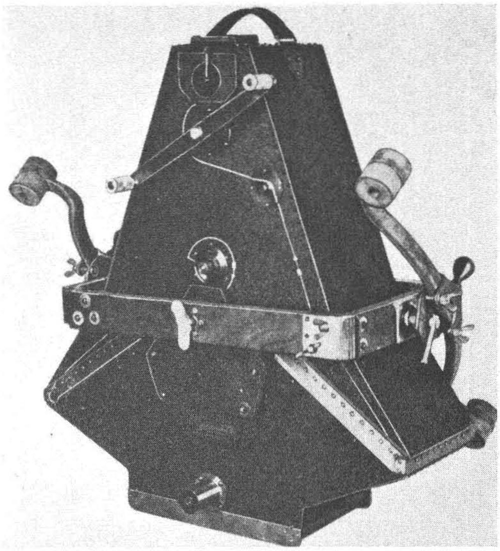

FIG. 1. T-1 Camera (side view).

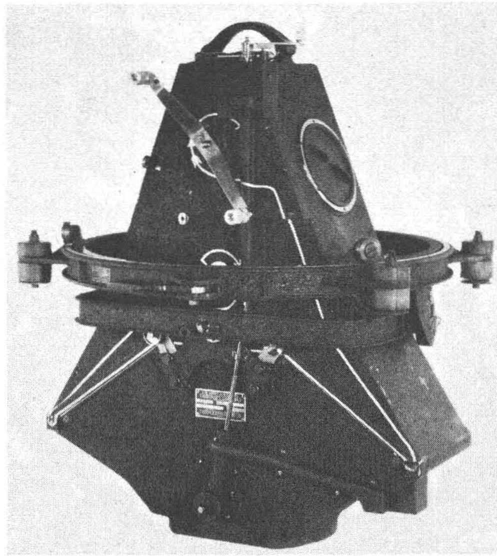

FIG. 3. T-2 Camera (side view).

early 1920's. The T-1 (Figure 1) was a three-lens camera having a $6\frac{1}{2}''$ focal-length lens set vertically, flanked on each side by a $7\frac{1}{4}''$ focal-length lens, each positioned at a 35° dihedral angle with the vertical. It had an F/4.5 aperture and a 1/50 second shutter speed. It was equipped with a glass focal-plane and a between-the-lens shutter. Apparently, no cameras were produced other than the prototype (Figure 2).

The *Type T-2 tactical mapping camera* was similar to the T-1 except that it had an additional $7\frac{1}{4}''$ focal-length lens set at a 35° angle with the vertical lens and at a 90° angle in orientation from the other lenses (Figures 3 and 4). All shutters were tripped simultaneously by means of a four-pronged plunger actuated by a handle on the magazine. The aerial coverage of the T-2 camera is shown in Figure 5. Ten of these cameras were manufactured for the Air Corps. The *T-2A camera* differed from the T-2 in that it had a vacuum focal-plane instead of an open frame. Sixteen of these were produced.

The *Type T-3 camera* (Figure 6) was the first truly standard mapping camera. Its five lenses all were of 6″ focal-length. The lenses were clustered with a central one aimed vertically, and the other four placed at 90° intervals around the central lens and tilted at 43° angles of obliquity. The lenses of the T-3 camera had F/6.8 apertures, and $5\frac{1}{2}'' \times 6''$ negatives were produced from each lens (Figure 7). The *T-3A camera* differed from the T-3 in that it had a choice of three shutter speeds instead of the fixed 1/50 second speed (Figure 8).

A tandem T-3A configuration was used in mapping during the 1930's (Figure 9). The resultant rectified mosaic, produced from one vertical and eight oblique prints, took the form of an octagon (Figure 10). It produced a total angular coverage of about 140°. Control

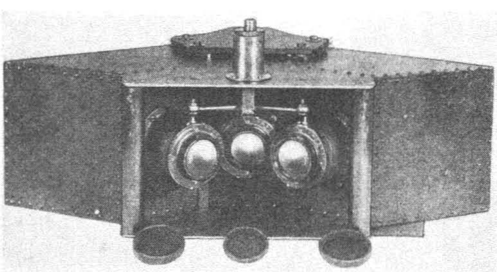

FIG. 2. T-1 Camera (bottom view).

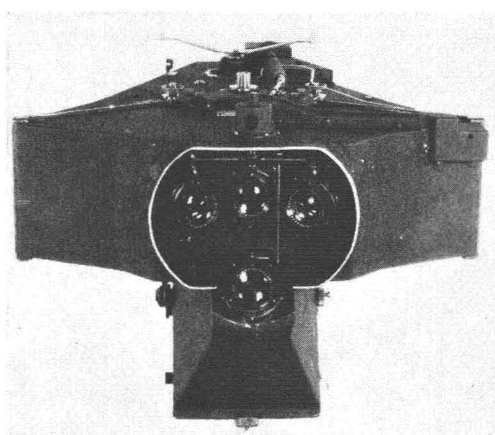

FIG. 4. T-2 Camera (bottom view).

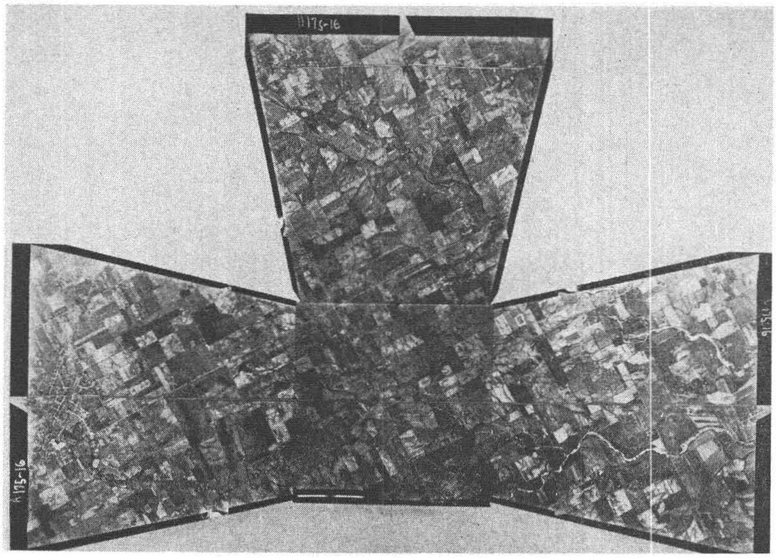

FIG. 5. T-2 Camera Coverage.

between prints was effected through a slight overlap of coverages. One T-3 and twelve T-3A cameras were built for the Air Corps.

The use of the *Types T-4 and T-4A camera* is obscure, as well as the reason for their having been listed in the mapping series (in the literature they were referred to as "spotting cameras"). The T-4 camera had a single lens of 10″ focal-length covering a $4\frac{1}{2}'' \times 6''$ format. It had the only focal-plane shutter in the mapping camera series, and was equipped with a glass focal-plane. The T-4A differed from the T-4 in that its format measured $5\frac{1}{4}'' \times 6''$. Seven T-4A cameras were produced.

Although it was not a true mapping camera, the *K-3B camera* should be mentioned in this treatise by virtue of its use in a large number of mapping operations during the 1930's. It was built originally as a general purpose camera for either oblique or vertical photography. The K-3B camera was equipped with interchangeable lens cones of 6″, $8\frac{1}{4}''$, 12″ and 24″ focal-lengths. It had a between-the-lens shutter and a vacuum back. It produced negatives of $7'' \times 9\frac{1}{8}''$ or $9'' \times 9''$, as desired. While built as a precision instrument, its initial construction preceded the advent of stereoscopic mapping in this country and thus it lacked provision for exactly collimating the film with the taking lens. It served a purpose in providing a versatile, single-lens camera during the period following the mul-

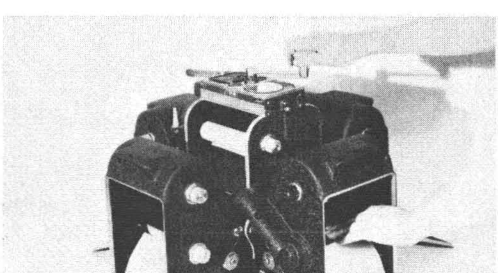

FIG. 6. T-3A Camera.

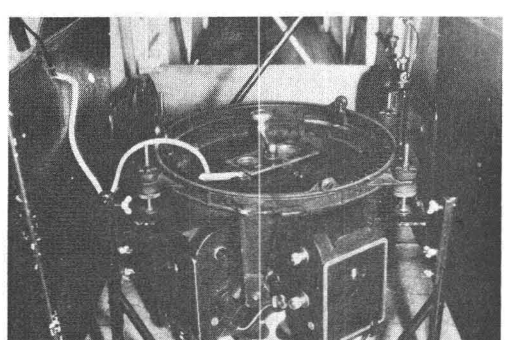

FIG. 7. T-3A Installation.

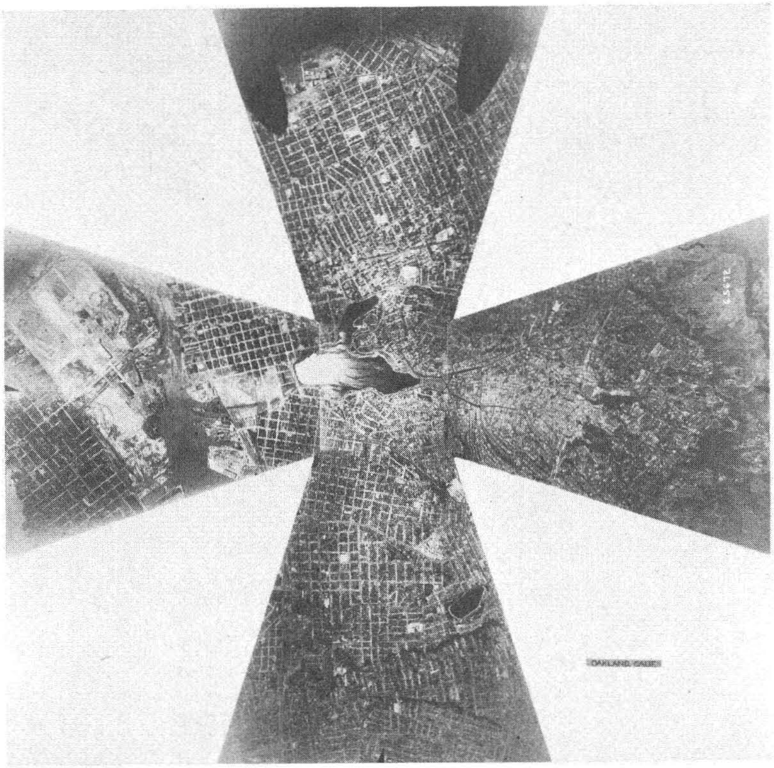

FIG. 8. T-3A Camera Coverage.

tiple-lens T-3A development and prior to the advent of the T-5 camera.

III. MIDDLE PERIOD CAMERAS (1940–1950)

The *Type T-5 camera* development was started in 1938 at the request of the Corps of Engineers to fulfill a need within the Army for a precision, wide-angle, single-lens mapping camera. Prior to that time, wide-angle mapping coverage was obtained with the multiple-lens T-3A camera. In 1937, the Bausch and Lomb Optical Company successfully produced the 6″ Metrogon lens which had an angular field of 93°, good resolution, and, for that time, relatively small distortion. In July, 1940, the first experimental T-5

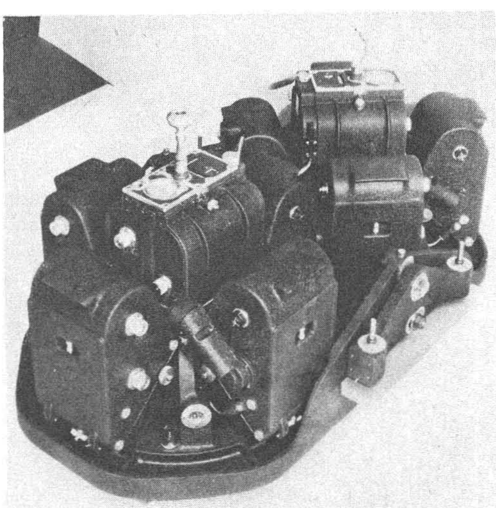

FIG. 9. Tandem T-3A Cameras.

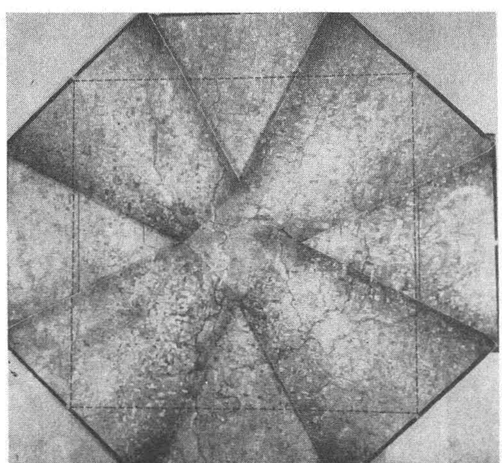

FIG. 10. Tandem T-3A Camera Coverage.

FIG. 11. T-5 Camera.

camera incorporating the Metrogon lens was delivered for testing. It was built by Fairchild Camera and Instrument Corporation. By August, 1945, 79 standard cameras had been produced for field use (Figures 11 and 12).

The T-5 camera featured the following:

1. Lenses selected for a definite distortion curve,
2. A fixed relationship between the lens and the focal plane,
3. Fiducial markers set at the focal plane in the lens cone,
4. An anti-vignetting lens filter with faces parallel within 10 seconds of arc,
5. A built-in viewfinder,
6. A built-in exposure meter,
7. A built-in intervalometer,
8. Recording between frames on film of exposure number, tilt bubble, clock, altimeter, and data card information, and
9. A film magazine holding 200 feet of $9\frac{1}{2}''$ film.

The T-5 camera, when delivered, satisfactorily produced precision photography and was subsequently standardized. However, the many innovations in design caused difficulties in keeping it maintained properly during operational use, and it was placed in limited standard status.

The *Type XT-6 camera* was built by Fairchild Aerial Survey for its own work; one of these cameras was purchased for study by the Air Corps in 1940. The camera did not conform to Air Corps specifications and could not be considered for standardization, but it did provide an opportunity for testing the feasibility of using a 12″ focal-length Metrogon lens and an $18'' \times 18''$ negative size for mapping use (Figures 13 and 14). After World War II, attempts made to obtain photography with this camera at a 40,000-foot altitude failed because of mechanical difficulties. Results of comparison between photography taken with the XT-6 and that taken with the T-5 camera were inconclusive be-

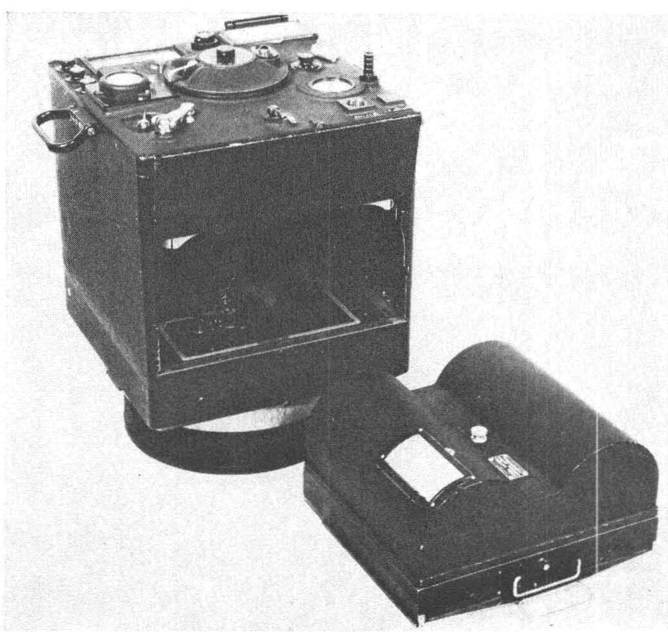

FIG. 12. T-5 Camera (magazine exposed).

cause of the previously mentioned problems with the XT-6 operation. After giving some consideration to building a new 18″×18″ camera, the Air Force finally dropped the project in 1950.

The *Type T-7 camera* was developed as a three-lens camera for use in trimetrogon charting. One such camera was built by the Fairchild Camera and Instrument Corporation during the late 1940s. It featured three 6″ Metrogon lenses in an integral camera casting at trimetrogon locking angles of 60°, and its magazine had a 390-foot film capacity (Figure 15). The camera operated satisfactorily. However, the design of many aircraft would not permit installation of this type of camera. Consequently, further development of this design was abandoned, and use of the original trimetrogon (three *K-17 cameras*) installation was continued (Figure 16).

The *T-8 camera* program was developed to provide, as quickly as possible, a mapping camera for replacement of the T-5 camera for domestic and foreign use. The program was initiated in 1948 to modify existing *K-17 reconnaissance cameras* having selected Metrogon lenses with the addition of an A-9 magazine for larger film capacity and with the lens cone and camera body doweled to the magazine for greater stability (Figure 17). The doweling was designed to fulfill the requirement for maintaining a fixed relationship between the fiducial markers on the focal-plane and the camera lens. However, the arrangement required that each camera and magazine combination be maintained as a unit; this served to delete the advantage of interchangeability of magazines and lens cones and also, no provisions were made for flatter vacuum backs. So the cameras still failed to meet precision mapping camera requirements. Approximately 50 cameras were

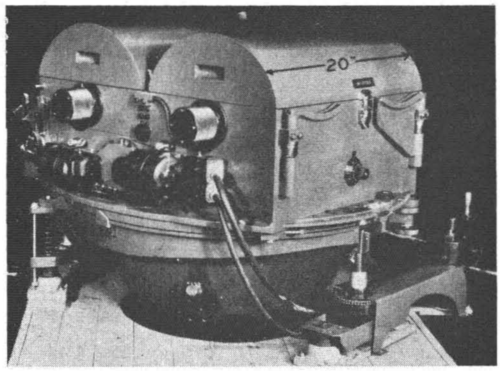

FIG. 14. XT-6 Camera (left side).

modified under the direction of Air Materiel Command.

The *Type T-9 mapping camera* was developed for two purposes. One was to provide a precision mapping camera capable of testing the merits of image-motion compensation in mapping photography. The other was to provide a prototype of a camera to be considered as a possible replacement for the T-5 cameras. The T-9 featured optional image-motion compensation, a 6″ Metrogon lens, a new shutter design, a new type magazine and data recordings (Figure 18). One camera, built by Fairchild Camera and Instrument Corporation, was delivered in January, 1949. During the course of the tests much trouble was experienced with the general maintenance of the camera. The new single-leaf shutter performed so unsatisfactorily that it was necessary to confine its operation to speeds slower than 1/150 second. The image-motion compensation feature appeared to perform within the degree of accuracy with which the ground speed and altitude could be determined. However, the need for IMC at the altitudes at which mapping photography was

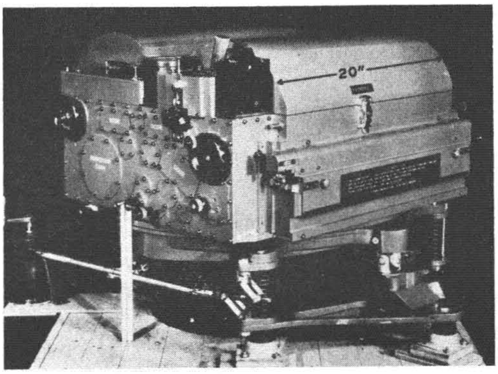

FIG. 13. XT-6 Camera (right side).

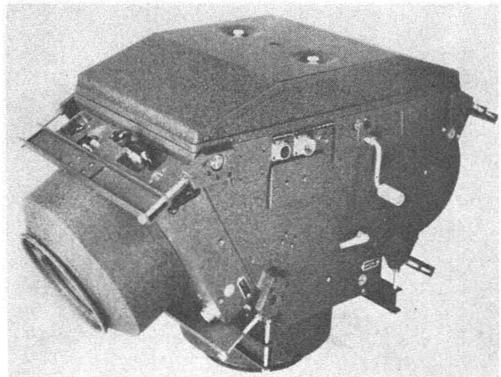

FIG. 15. T-7 Camera.

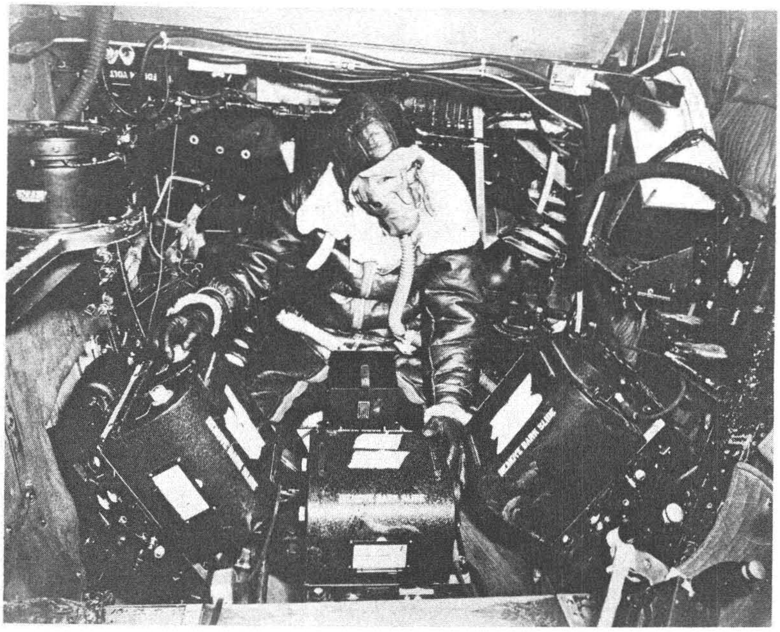

FIG. 16. Tri-Metrogon Camera Installation.

flown and at the airplane speeds of that era was questionable. So further development was dropped.

In 1947, a program was initiated to modify all existing *T-5 cameras* by the removal of certain accessory equipment. These accessories included the intervalometer, the light meter, the level bubble and some of the recording light wiring and switches. These modified cameras were referred to as *Type T-5A* and were prototypes for a proposed camera to be designated as *Type T-10*. Recommendation by the Photographic Laboratory to have the T-10 standardized so that quantity procurement could be made was disapproved in August, 1947, by Hq. USAF. The decision was based on the assumption that the T-9 camera was nearly ready for standardization. Hence, no T-10 cameras were fabricated (Figure 19).

IV. LATER CAMERAS (1951–1963)

In the late 1940's the *Fairchild Cartographic Camera* was developed. It was based on the reliable K-17 reconnaissance camera but had the fiducial markers and lens located in an inner cone (Figure 20). This camera offered the advantages of tested mechanical components plus the precision required for mapping photography. The quality of the photography was the same as that of the T-5 and T-9 cameras since it was equipped with a

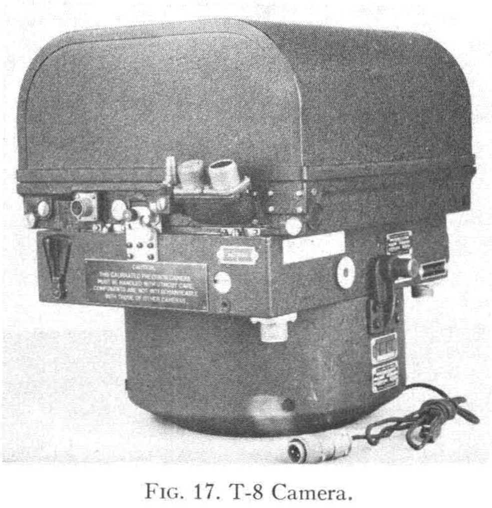

FIG. 17. T-8 Camera.

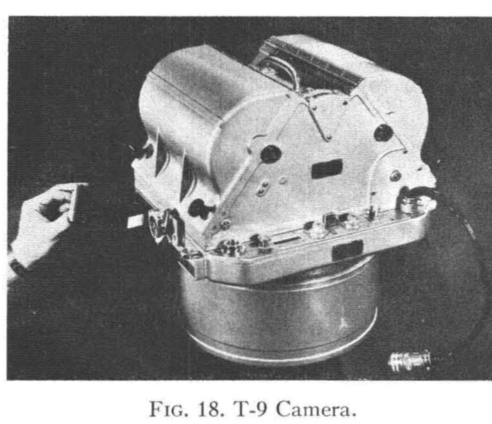

FIG. 18. T-9 Camera.

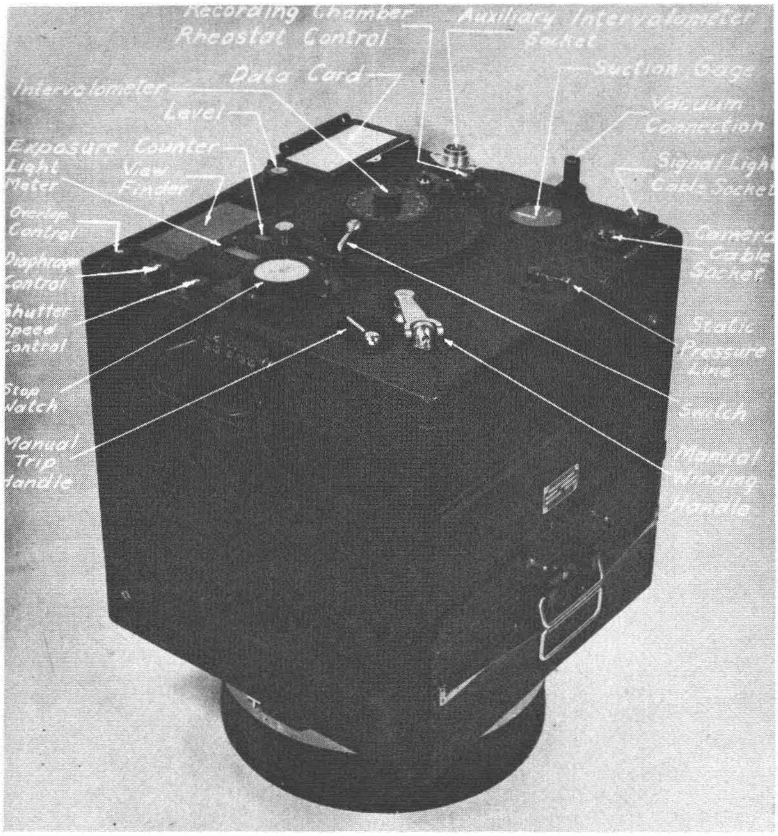

FIG. 19. T-10 Camera.

selected Metrogon lens, but it did not meet USAF and Corps of Engineers specifications in that it lacked provisions for data recording.

Because of the desirable features of ruggedness, simplicity and precision in the Cartographic Camera, it was decided to develop a similar camera for military mapping use which would also have data recordings. This camera, typed *the T-11*, was basically a Cartographic Camera with a Willcox shutter and the necessary data recordings added to fulfill mapping requirements (Figure 21). Delivery of the camera by Fairchild began in February, 1951, and was continued until 1954, by which time about 1100 cameras had been produced.

The T-11 camera proved to be the most successful military mapping camera developed up to that time. It possessed precision, automatic features, and a high degree of reliability. Its development was concurrent with that of the Type A-28 gyroscopically stabilized aerial camera mount, the first of a series of mounts designed to reduce tilts in aerial photography and to improve photographic resolution by decreasing aircraft vibration effects. The T-11 camera still is used to a great extent in military mapping and charting operations.

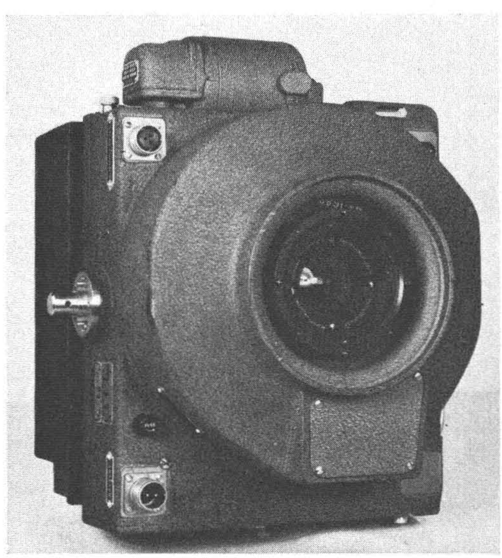

FIG. 20. Cartographic Camera.

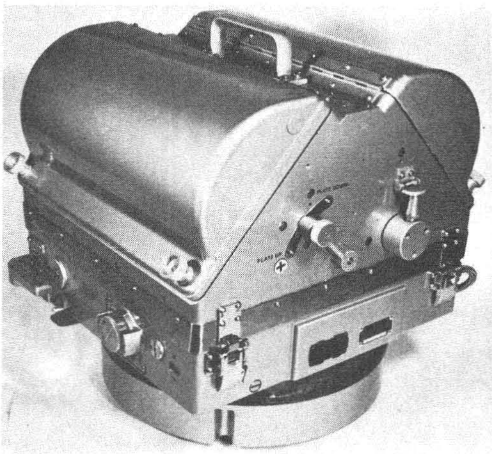

FIG. 21. T-11 Camera.

The Metrogon lens of the T-11 camera has maximum radial distortions in the order of about 125 microns. This amount of distortion is corrected in multiplex mapping by the use of a reverse curve in the optical system of the reduction printer in which is printed glass diapositives for use in the stereoplotter. In the Kelsh plotter this correction is accomplished by a special cam. Metrogon lenses were selected for installation in mapping lens cones by examination of the distortion curves which were determined in calibration. The curve at any point must be enclosed in an envelope, the limits of which are formed by a 5-micron tolerance on each side of the established nominal correction curve. Thus, positions of points anywhere on the stereo model theoretically may be determined to ±5 microns. However, the advantages of a lens as nearly distortion free as possible was apparent, and the test of such a lens was the next step in military mapping camera development.

Following World War II, a prototype model of a new distortion-free, wide-angle Topogon lens of 100-millimeter focal-length was discovered in Germany. The lens was brought to this Country and turned over to Air Materiel Command for study. In June, 1947, a contract was let to Bausch and Lomb Optical Company for an evaluation of the lens. This company was successful in determining the lens formula and in modifying it to use American glass. As part of this contract, Bausch and Lomb fabricated three lenses in each of three focal-lengths (4″, 5″, and 6″). One of the 6″ lenses was installed in a cartographic camera for performance testing and for comparison with the Standard Class "T", 6″ Metrogon lens. The optical characteristics of this lens and a typical Metrogon lens, as determined in the camera calibration process, showed that the Topogon lens was slightly higher in photo-resolution than the Metrogon, and that its distortion was about 20 microns compared to 110 for the Metrogon. The findings at Wright-Patterson Air Force Base were verified by the National Bureau of Standards.

Although the Topogon V lens proved to be non-distortionless, its improvement in quality over the Metrogon lens was deemed to be sufficient to warrant the development of an improved mapping camera which was initially typed the *T-12*. This designation was changed shortly to *Type KC-1*, and the name of the lens was changed to "*Planigon*". During 1954 and 1955 about 122 KC-1 cameras were produced by Fairchild Camera and Instrument Corporation. The Planigon lenses were fabricated by Bausch and Lomb, the Curtis Laboratories, and Goerz American Optical Company. In addition, some extra lens cones and several hundred spare planigon lenses were built.

In appearance the KC-1 camera is much like the T-11 (Figure 22). The dust cover of the KC-1 is about an inch deeper to accommodate the slightly longer Planigon lens, and two of the KC-1 shutter trip rods are slightly longer. Radial distortions in the KC-1 cameras vary from about 5 to 25 microns, tangential distortions are under 10 microns, and photo resolutions average about 24 lines/mm. AWAR (Figure 23).

With the advent of high altitude aircraft, it was decided in 1957 to modify selected KC-1 cameras by the substitution of a newly developed 80,000-foot barometric altimeter for the conventional 50,000-foot altimeter. These cameras were typed *KC-1A*, and the value for lens distortion in the specification was reduced to 12 microns. It is understood that about 20 of the original production of KC-1s have been converted to KC-1A.

A further modification of the KC-1 camera was initiated in 1959. In order to remain compatible with advances in stereoplotting development and to make possible the elimination of distortion-correction devices, it was decided by the Air Force to develop a more accurate mapping camera without the need of an R&D program. Consequently, a contract was awarded by Mobile Air Materiel Area to Fairchild Camera and Instrument Corporation for the substitution of low-distortion spare Planigon lenses in depot stock for those in existing high-distortion (15–25 microns) KC-1 cameras. This *KC-1B* modification requires that lens distortions, both radial and tangential, be 10 microns or less, that the camera be equipped with the 80,000-foot barometric altimeter, and that the magazine platen be ground to a flatness of 0.0002″. To date about 40 of the KC-1 cameras have been converted to KC-1Bs.

In the meantime other mapping camera developments had been in progress. One of these was motivated by the trend in the latter 1950's toward convergent photography. A convergent camera installation involves the suspension of two mapping cameras, preferably with distortion-matched lenses, in such a manner that their optical axes are each 20° off the vertical and are separated by a 40° locking angle. The resulting simultaneous exposure produces a pair of prints which overlap slightly for control. When flown with camera axes in line of flight, it is possible to obtain a base-height ratio twice that of the 60% overlap, 6″ vertical mapping photography, and thus, to achieve a capability for producing contour intervals at twice the *C*-factor for the vertical photography compilation.

The first convergent installation tested by the Air Force was the twinplex system, developed by the U. S. Geological Survey, which consisted of two T-11 or KC-1 cameras held at the appropriate fixed angle in a gravity suspension mount (Figure 24). Later, the ART-23, a torquer stabilized mount was developed by Aeroflex Laboratories to hold two KC-1 cameras in a convergent installation

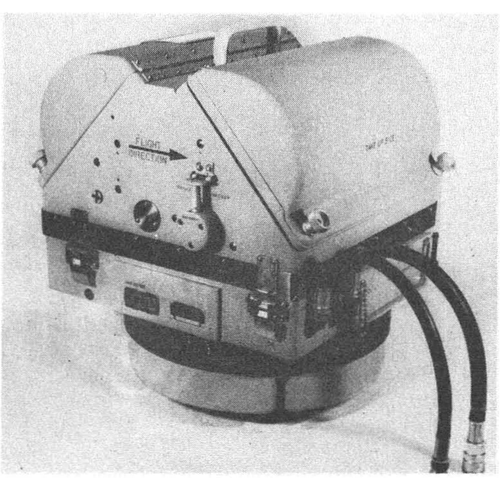

FIG. 22. KC-1 Camera.

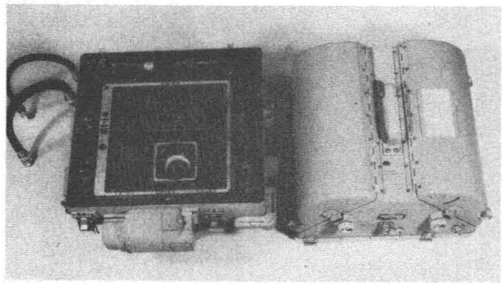
FIG. 23. KC-1 Camera (showing Planigon lens corrector).

in the Air Force's RC-130A mapping system.

In order to have a convergent camera system as an integral component, the Air Force awarded a contract to Fairchild Camera and Instrument Corporation in 1958 to build the *Type KC-2 camera*. This camera held two matched 6″ Planigon lenses which were mounted at the appropriate angle in an integral camera casting (Figure 25). Each lens cone had its separate magazine system (Figure 26). The package development included the camera, a special ART-24 mount, and a thermal barrier (which enclosed the camera and mount to provide a constant environment).

About the time that the development of the KC-2 camera was complete, the military interest in convergent mapping photography began to wane. Although the convergent photography increased the worth of topographic detail on the map, evaluations showed that some loss occurred in the positional accuracy of planimetric detail.

Concurrently, another trend had been developing in this country to build a military capability for ultra-wide-angle mapping. The European countries, in particular, had been mapping with ultra-wide-angle cameras for several years to take advantage of the greater coverage afforded. Consequently, the Air Force in 1960 awarded a contract to Aeroflex Laboratories to build the *KC-3 camera* as a military version of the *Wild RC-9 ultra-wide-angle mapping camera*. This particular negotiation was handled as a product improvement rather than an R&D development. Two cameras were built by mounting the 88 mm. ($3\frac{1}{2}$″) Super-Aviogon lenses of the Wild RC-9 camera in KC-1 type camera bodies (Figures 27 and 28). The camera produced 120° ultra-wide-angle-coverage, along the diagonals, on a 9″×9″ format.

The *KC-3 camera* has several new features

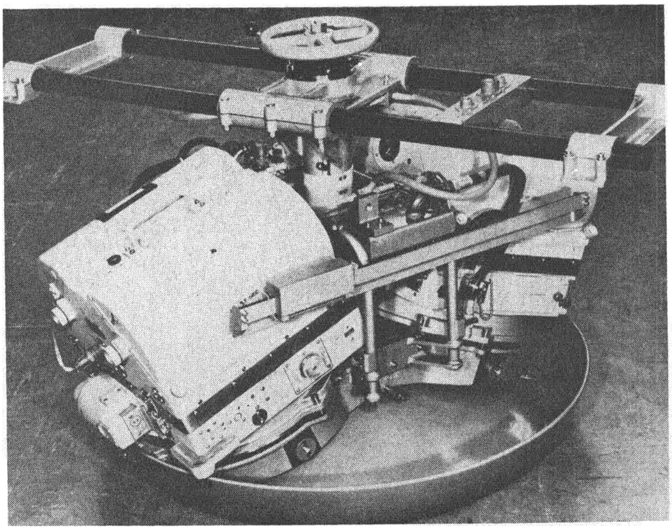

FIG. 24. Convergent Camera Installation, Twinplex.

It has a platen reseau, or grid, the intersections of which are 0.004″ diameter openings filled with lucite for light distribution. It has a newly-developed, transistorized, electromagnetic shutter. The KC-3 camera can be installed in the same series of gyroscopically stabilized camera mounts as the T-11, KC-1, and KC-4 cameras. One KC-3 camera was delivered to the Aeronautical Systems Division in October, 1961, and the other in April, 1962. These cameras presently are in preliminary operational use by Air Photo & Charting Service, who will provide test photography soon for mapping evaluation. The ultra-wide-angle camera has been called out in the Air Force's AN/USQ-28 Mapping and Survey Subsystem, Geodetic, as an alternate installation to the 6″ prime vertical camera.

During these latter years, progress was being made in research on lens design. As early as 1955, Dr. James Baker was commissioned by the Air Force to design a low-distortion mapping lens which would have a higher amount of photo resolution than the current Metrogon and Planigon lenses; these average about 22 and 24 lines/mm., respectively, in AWAR. The resulting Type T-11 lens, later called the Geocon I, proved to have lens distortions of less than 10 microns; its resolution measured 52 lines/mm. on-axis and 35 lines/mm. AWAR. The lens was mounted in a T-11 camera body for flight testing. The full F/5.6 speed of the lens, however, could not be realized in the prototype camera, which produced a maximum aperture of only F/8. This camera subsequently was used in high-speed, high-altitude flight tests.

In 1960, a contract was awarded to the Fairchild Camera and Instrument Corpora-

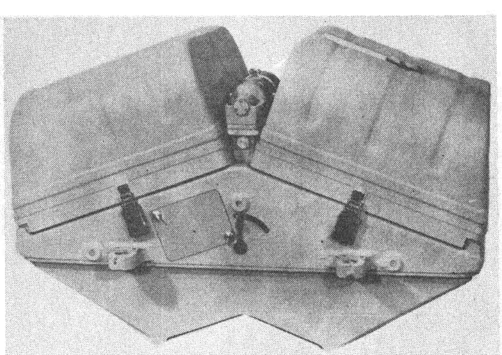

FIG. 25. KC-2 Camera (side view).

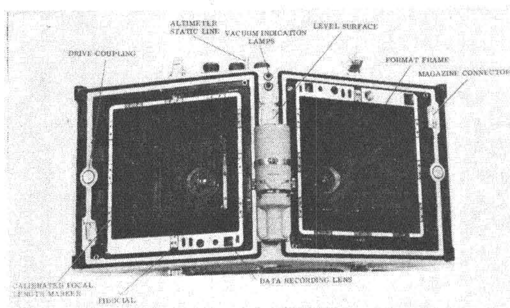

FIG. 26. KC-2 Camera (showing lenses).

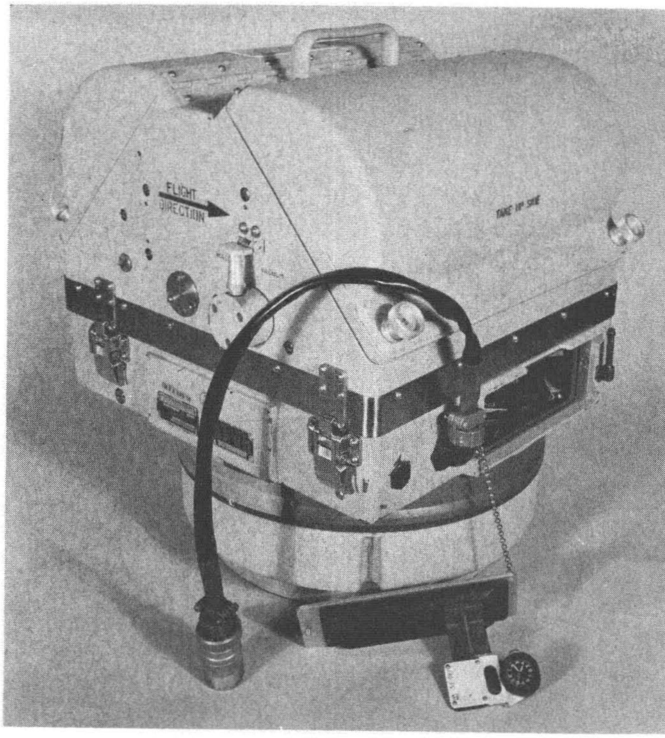

FIG. 27. KC-3 Camera (with data chamber removed).

tion for the production of one Type KC-4 camera holding the 6″ Geocon I lens, and capable of using its full F/5.6 aperture (Figure 29). The Perkin-Elmer Corporation was the fabricator of the lens. This camera was delivered to Aeronautical Systems Division in February, 1963. The *KC-4 camera* has a clear anti-vignetting filter which will permit the acquisition of color photography. High-altitude flight tests with both black and white and color film are pending.

The *KC-5 type* designation was issued to the Signal Corps, U. S. Army, for assignment to a miniaturized mapping camera which was to be transported in a drone vehicle. It is understood that the development of this item has never been pursued.

The most recent addition to the history of mapping cameras has been the *KC-6A camera*. This is to be the primary sensor in the Air Force's AN/USQ-28 Mapping Subsystem, the contract for which was awarded in November, 1962.

Indications are that the KC-6A mapping camera will be capable of producing acceptable mapping photography under practically any flight environment. Its Geocon IV lens, designed by Dr. James Baker, will not only have radial and tangential distortions of less than 8-microns magnitude, but it will provide a resolving power considerably higher than other existing mapping lenses. Other features, such as automatic exposure control, appear in a standard military mapping camera for the first time.

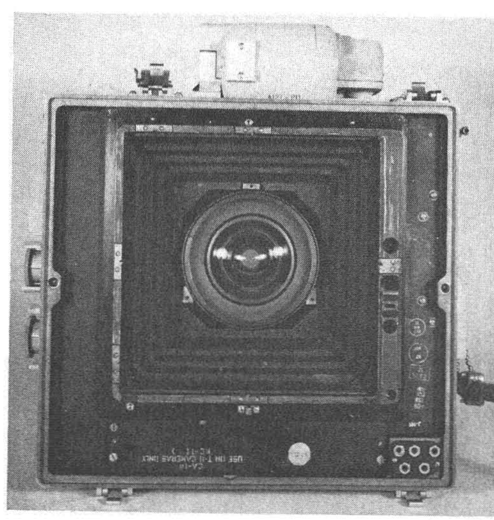

FIG. 28. KC-3 Camera Body (top view).

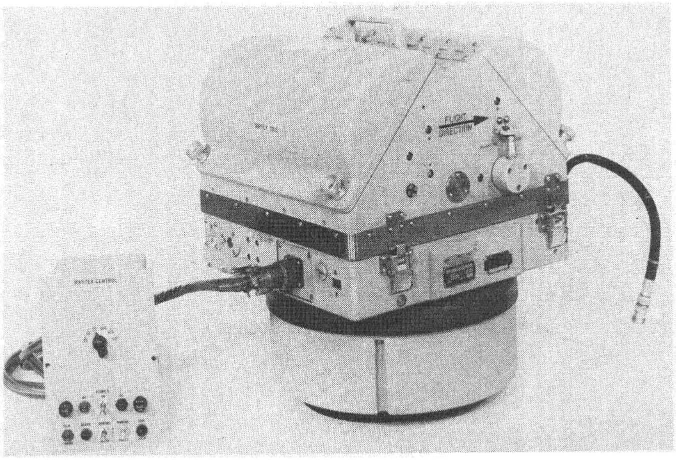

FIG. 29. KC-4 Camera.

The characteristics of the *KC-6A mapping* camera are as follows:

1. Its lens is a Geocon IV with focal-length of 6″.
2. Its format size is 9″×9″.
3. Its maximum aperture is F/5.0.
4. It has an intra-lens shutter with speed range of 1/100 to 1/800 second.
5. Its magazine holds 390 feet of $9\frac{1}{2}$″ film of standard thickness.
6. It has an optional image-motion compensation feature, located in the magazine. Its IMC velocity range varies from 0.1 to 0.8 inch per second.
7. Its automatic exposure is self-contained in the camera. It performs with errors not exceeding $\pm\frac{1}{2}$ the equivalent F-stop of the manually set values of shutter and diaphragm.
8. Four conventional fiducial markers, illuminated by natural light, when exposed on film, locate the principal point of the lens within a tolerance of 0.010 millimeters. Two auxiliary fiducial markers, exposed by artificial light, are located on opposite sides of the format to assist in establishing the position of the principal point on the film when the IMC feature is used.
9. The camera has a reseau platen whose grid intersections are separated by two-inch distances. Means are provided for positioning the platen with respect to the lens which assures that the platen will return to its correct position whenever the magazine is removed, then reinstalled.
10. The camera is furnished with an initiation signal which is activated when the shutter has reached the midpoint of exposure. This signal permits the recording of auxiliary data within one millisecond of the midpoint of the camera exposure for all shutter speeds.
11. The maximum shutter cycling rate is two seconds per exposure.
12. The radial and tangential distortions in the lens system are not greater than 8 microns.
13. Although not yet tested, the photographic resolution of the camera system, based on measurements of USAF high contrast targets exposed on topographic base film, should produce an AWAR of about 45 lines/mm.

In general this item embodies an advanced state of the art in mapping camera development. Several of its features, such as IMC, automatic exposure control, and accurate shutter synchronization, should permit its use in combat mapping and other areas of effort in which exist stringent requirements imposed by speed, altitude, inaccessibility and other environmental factors. The camera is being fabricated by Fairchild Camera and Instrument Corporation. It should be available the latter part of 1963.

Table 1 (in two parts) provides the characteristics of all military mapping cameras produced to date by the United States Air Force. It covers a period during which a very close spirit of cooperation has existed between Air Force and Army personnel who have been involved therein.

The author wishes to express his appreciation to Mr. Leonard W. Crouch and Mr. William Pershing, both of Photo and Optics Section, Reconnaissance Laboratory, ASD, and to Mr. James Young, Photo-Optical Section, Reconnaissance Systems Division, ASD, all of whom contributed information for the writing of this report.

The author also wishes to thank Mr. Herbert Meade, Fairchild Camera and Instrument Corporation, for his help in providing photographs of several cameras, including the Types T-7 and KC-4.

TABLE 1

CHARACTERISTICS OF MILITARY MAPPING CAMERAS

Type	*Status*	*Purpose*	*No. of Lenses*	*Focal Lengths*	*Type of Shutter*	*Focal Plane*	*Aperture*
T-1	Obsolete	Tact. Map.	3	$6\frac{1}{2}$–$7\frac{1}{4}$	Bet. Lens	Glass	F/4.5
T-2	Obsolete	Tact. Map.	4	$6\frac{1}{2}$–$7\frac{1}{4}$	Bet. Lens	Open Frame	F/4.5
T-2A	Obsolete	Tact. Map.	4	$6\frac{1}{2}$–$7\frac{1}{4}$	Bet. Lens	Vacuum	F/4.5
T-3	Exper.	Tact. Map.	5	6″	Bet. Lens	Vacuum	F/6.8
T-3A	Obsolete	Tact. Map.	5	6″	Bet. Lens	Vacuum	F/6.8
T-4	Exper.	Spotting	1	10″	Focal Plane	Glass	F/4.5
T-4A	Obsolete	Spotting	1	10″	Focal Plane	Glass	F/4.5
T-5	Obsolete	Mapping	1	6″	Bet. Lens	Vacuum	F/6.3
XT-6	Exper.	Mapping	1	12″	Bet. Lens	Vacuum	F/6.3
T-7	Exper.	Trimet. Map.	3	6″	Bet. Lens	Vacuum	F/6.3
T-8	Exper.	Mapping	1	6″	Bet. Lens	Vacuum	F/6.3
T-9	Exper.	Mapping	1	6″	Bet. Lens	Vacuum	F/6.3
T-10	Exper.	Mapping	1	6″	Bet. Lens	Vacuum	F/6.3
T-11	Ltd. Std.	Mapping	1	6″	Bet. Lens	Vacuum	F/6.3
KC-1	Ltd. Std.	Mapping	1	6″	Bet. Lens	Vacuum	F/6.3
KC-1A	Ltd. Std.	Mapping	1	6″	Bet. Lens	Vacuum	F/6.3
KC-1B	Standard	Mapping	1	6″	Bet. Lens	Vacuum	F/6.3
KC-2	Exper.	Conv. Map.	2	6″	Bet. Lens	Vacuum	F/6.3
KC-3	Alt. Std.	UWA Map.	1	88 mm.	Bet. Lens	Vacuum	F/5.6
KC-4	Exper.	Mapping	1	6″	Bet. Lens	Vacuum	F/5.6
KC-6A	Devel.	Mapping	1	6″	Bet. Lens	Vacuum	F/5.0

TABLE 1 (*Continued*)

CHARACTERISTICS OF MILITARY MAPPING CAMERAS

Shutter Speeds	*Negative Size*	*Film Size*	*Exposure per Loading*	*Mount Used*	*Cover-age*	*Wt. of Camera*	*No. Pro-duced*	*Type*
1/50	$5\frac{1}{2}$×6	6″×380′	190	A-2	120°	40	1	T-1
1/50	$5\frac{1}{2}$×6	6″×380′ 6″×105′	190	A-4	120°	51	10	T-2
1/50	$5\frac{1}{2}$×6	6″×380′ 6″×105′	190	A-4	120°	58	16	T-2A
1/50	$5\frac{1}{2}$×6	6″×140′	250	A-5	140°	50	1	T-3
1/25, 1/50	$5\frac{1}{2}$×6	6″×120′	200	A-5A	140°	71	12	T-3A
1/50, 1/200	$4\frac{1}{2}$×6	6″×105′	200	None	33°	21	0	T-4
1/50, 1/200	$5\frac{1}{4}$×6	6″×105′	200	A-7	33°	29	7	T-4A
1/50, 1/300	9×9	$9\frac{1}{2}$″×200′	225	A-22	90°	76	79	T-5
1/35, 1/150	18×18	$18\frac{1}{2}$″×1000′	600	Fixed	90°	300	1	XT-6
1/50, 1/400	9×9	$9\frac{1}{2}$″×390′	440	Fixed	90°	180	1	T-7
1/50, 1/400	9×9	$9\frac{1}{2}$″×390′	440	A-22	90°	60	50	T-8
1/60, 1/500	9×9	$9\frac{1}{2}$″×390′	440	Special	90°	80	1	T-9
1/50, 1/300	9×9	$9\frac{1}{2}$″×200′	200	A-22	90°	70	0	T-10
1/75, 1/500	9×9	$9\frac{1}{2}$″×390′	440	A-28	90°	75	1100	T-11
1/75, 1/500	9×9	$9\frac{1}{2}$″×390′	440	ART-25	90°	80	122	KC-1
1/75, 1/500	9×9	$9\frac{1}{2}$″×390′	440	ART-25	90°	80	20*	KC-1A
1/75, 1/500	9×9	$9\frac{1}{2}$″×390′	440	ART-25	90°	80	40*	KC-1B
1/50, 1/700	9×9	$9\frac{1}{2}$″×250′	275	ART-24	90°	75	1	KC-2
1/100, 1/800	9×9	$9\frac{1}{2}$″×390′	440	ART-25	120°	83	2	KC-3
1/25, 1/400	9×9	$9\frac{1}{2}$″×390′	440	ART-25	90°	98	1	KC-4
1/100, 1/800	9×9	$9\frac{1}{2}$″×390′	440	ART-25	90°	100**	27**	KC-6A

* Included in KC-1 Total **Estimated